number 13, june 2003

on station

The Newsletter of the Directorate of Human Spaceflight http://www.esa.int/spaceflight

in this issue

European Space Agency
Agence spatiale européenne

Directorate of Human Spaceflight
Direction des Vols Habité

Progress and Recovery

Jörg Feustel-Büechl
ESA Director of Human Spaceflight

Despite the inevitable delays in the ISS programme stemming from the *Columbia* accident, I am pleased to report that we continue to make good progress in preparing Europe's contributions. Columbus and the Automated Transfer Vehicle (ATV) are both well along in development, as are our ISS Utilisation plans, and we are also finding more flight opportunities for our astronauts.

Columbus is now right in the middle of its Qualification Review, which should be completed in September. Assembly of the basic module has been completed at Astrium in Bremen (D) and the payload facilities are being tested there in the Rack Level Test Facility (RLTF) before integration into Columbus.

Early next year, there will be a full compatibility test between the Columbus module and the complete ground segments within Europe and the US. This will mark the completion of the qualification process for Columbus. Then we shall reassess what needs to be done next, hopefully in conjunction with the post-*Columbia* Shuttle flight manifest. At the moment, the Columbus launch is still frozen at its pre-*Columbia* date of October 2004, but if the new manifest provides a different date we will accordingly adapt the shipment to the Kennedy Space Center (KSC) for launch processing. However, if the launch is significantly delayed, we must see whether we need to store Columbus or undertake further testing.

With the invaluable support of our ISS International Partners and industrial partners, we recently concluded the ATV Critical Design Review, culminating in the 4 June Board meeting. No show-stoppers were identified, so the project can continue into its final stage of manufacture and qualification. We are now looking anxiously towards Ariane-5 because that vehicle will carry ATV into orbit. Following the failure of the first uprated version last December, Ariane-5 has to make two verification flights with the Vulcain-2 engine and the new cryogenic upper stage. In addition, additional qualification is required for the storable-propellant upper stage that will be used for ATV's maiden flight in September 2004. Altogether, we are highly satisfied with the progress of the ATV and can only congratulate the industrial team, under the leadership of EADS Space Transportation, and our team in Les Mureaux (F). We still hope to be on time with ATV even though it is considered to be the most demanding space project ever undertaken in Europe because of its complexity.

The ESA payload facilities' integration into Columbus will be completed in October 2003. The Biolab, European Physiology Modules (EPM), European Drawer Rack (EDR) and Fluid Science Laboratory (FSL) are well along in their final development stages and are undergoing Columbus compatibility testing in the RLTF. Indeed, a very satisfying milestone was already reached at the end of May when Biolab was successfully tested in the RLTF. The external facilities – the European Technology Exposure Facility (EuTEF) and the Solar Monitoring Observatory (SOLAR), planned to be launched with Columbus – are making good progress and should be ready in time.

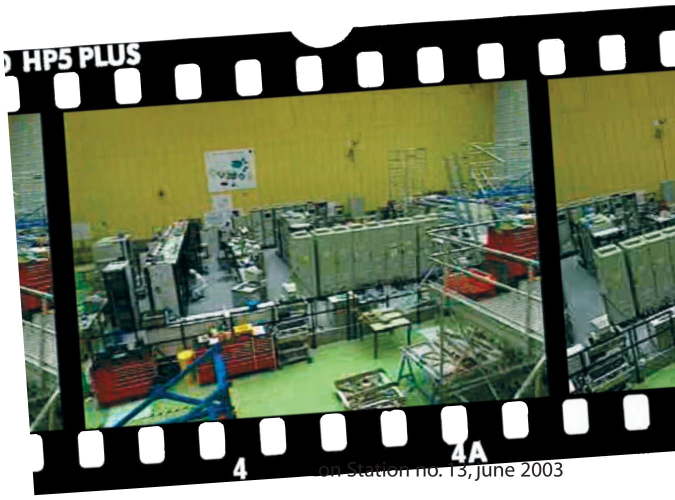
Soyuz-TMA2 at the Zarya nadir docking port. ESA Astronaut Pedro Duque will return to Earth in this spacecraft after delivering its replacement TMA3. (NASA)

So we hope that it will not be so long before we have our facilities up and running in space, providing versatile capabilities for our users and demonstrating Europe's strength in exploiting the ISS.

Three more European astronauts continue training to fly to the ISS, following in the footsteps of the first five Europeans who have been aboard the Station (Umberto Guidoni, I; Claudie Haigneré, F; Roberto Vittori, I; Philippe Perrin, F and Frank De Winne, B). We have already signed a contract with our Russian colleagues for the first of the new flights: Pedro Duque (E) will be the Flight Engineer aboard Soyuz-TMA 3 in October this year. We are working on another contract for André Kuipers (NL), to fly next April. Finally, Christer Fugelsang is assigned to a Shuttle mission sometime during 2004 but that is clearly dependant upon the resumption of Shuttle flights. We are confident that all these opportunities will materialise and be successful. They will bring the total of European astronaut visitors to the ISS to eight, showing that Europe, even without any real estate yet on-orbit, can provide regular flight opportunities to the Station. That capacity is extremely valuable for increasing our astronauts' expertise. Once Columbus is attached, of course, we expect an ISS resident crew to include an ESA astronaut.

On the Shuttle issue, we are looking for the resumption of flights as soon as possible. In July, we have a Heads of Agency meeting of the five International Partners in California. We expect to receive a full report from NASA on the *Columbia* Accident Investigation Board, as well as an indication of the Shuttle flight schedule required to complete ISS assembly. We also hope to reactivate the Programme Action Plan (PAP) that was put on hold after *Columbia*, finalising it as originally intended at the end of this year. This Plan was agreed among the Partners last December to bring the Station back to its original capabilities.

The very positive ESA Ministerial meeting on 27 May approved the unblocking of part of the



Claudie Haigneré

Roberto Vittori

Philippe Perrin

funding for the ISS Exploitation programme. We hope that the remaining funds can be unblocked by the end of this year. This is very much needed for our internal project management team, as well as for the ATV and Ariane-5 procurements. The reactivation of the PAP is therefore a key milestone in this unblocking exercise. This will allow ESA to support the continuing assembly of the ISS and demonstrate that, after *Columbia*, we need to rely on several options for ISS logistics support. Of course, we would like to have Columbus on-orbit as soon as possible in order to show to our user communities that we are open for research and business.

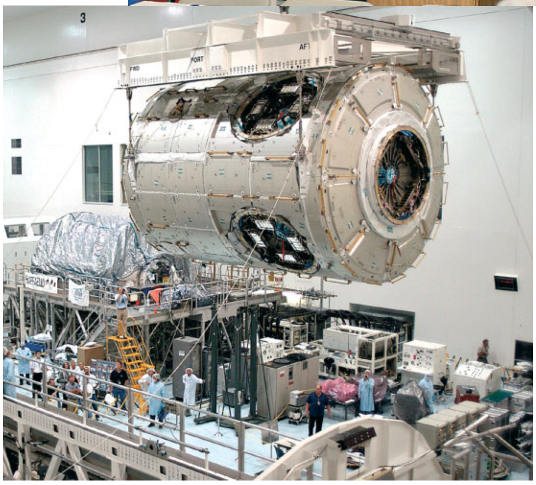
Over and above these major European elements, there has been major progress on other European projects. On 18 June, the transfer of Node-2 took place at KSC, with Alenia handing-over to ASI, ASI handing-over to ESA, and finally ESA handing-over to NASA (see pp4-6). Node-2 was not an easy project because it suffered a number of technical changes and problems with industrial labour conditions at Alenia. But now it has been completed and transferred to NASA, we can focus on building Node-3.

Europe's MELFI (Minus Eighty-degree Laboratory Freezer for the ISS) has long been at KSC. It was installed inside the Multi-Purpose Logistics Module (MPLM) ready for launch last March, and, post-*Columbia*, it is still waiting for its flight opportunity as part of the ULF-1 mission.

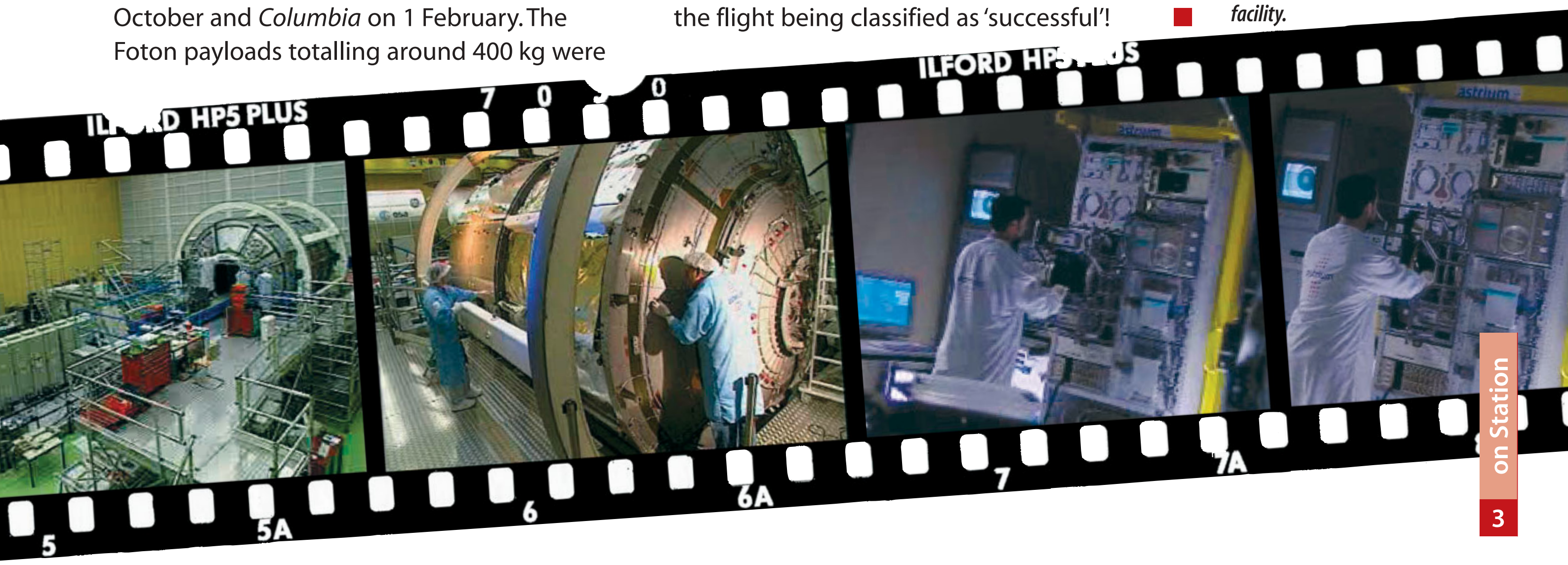
The European user community suffered badly from the loss of both Foton-M1 last October and *Columbia* on 1 February. The Foton payloads totalling around 400 kg were destroyed in the launch explosion. All returning biological and medical samples, as well as the research hardware, were lost during *Columbia*'s reentry: the results from four of the seven payloads were destroyed, but at least scientists have the downlinked data for the other three.

We are working towards reflights for our Foton users and have agreed with Rosaviakosmos on two further Foton missions. We are now investigating how best to use them, with the first planned for 2005. We are making similar efforts for our Shuttle users, but this is still in an early planning stage. The article on pp7-9 discusses the science loss and recovery in more detail.

And last, but not least, we had the successful Maxus-5 flight on 1 April. Although there was, unusually, little snow on top of the hill where Maxus landed, the bumpy return did not stop the flight being classified as 'successful'! ■



Node-2 is delivered. Alan Thirkettle, Head of MSM's Development Department, speaks at the 18 June ceremony in the Space Station Processing Facility marking the module's formal transfer to NASA. Japan's Kibo module was also accepted at the ceremony. To the left of Alan is KSC Director Roy Bridges; to his right is William Gerstenmaier (NASA ISS Program Manager), Andrea Lorenzoni (ASI Node-2 Programme Manager) and Kuniaki Shiraki (NASDA Kibo Project Manager).

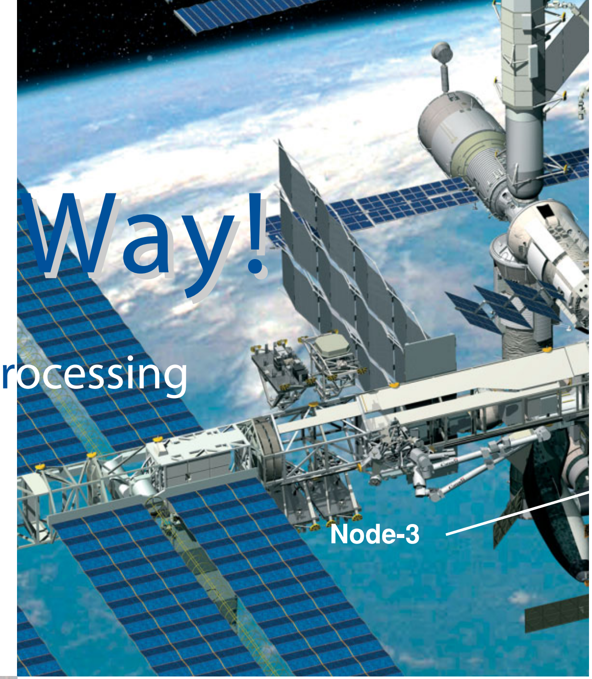


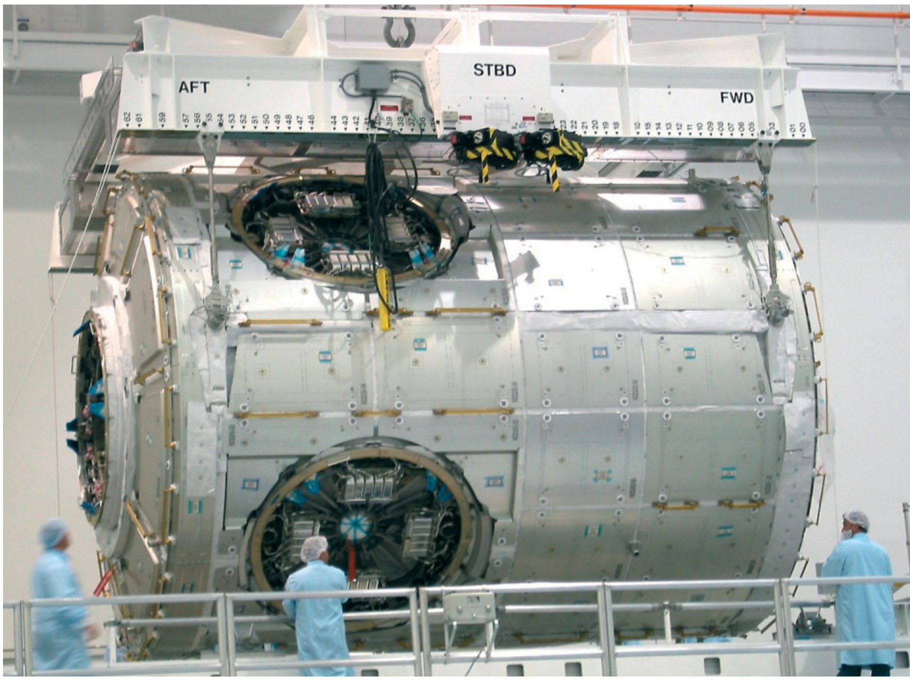
Columbus and Biolab at Astrium, in the Rack Level Test facility.

Node-2 Is On Its Way!

Crucial ISS Element is Delivered for Launch Processing

Daniele Laurini & Philippe Deloo
Development Department,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Daniele.Laurini1@jsc.nasa.gov; Philippe.Deloo@esa.int





Node-2 arrives in the Cape's Space Station Processing Facility.

The Delivery

The landing of the Airbus Beluga transport aircraft at the NASA Kennedy Space Center (KSC) landing strip on 1 June 2003 concluded the first step of a long trip that will eventually see Node-2 attached to the International Space Station (ISS), orbiting 380 km above our heads. This crucial ISS module was formally accepted by NASA at a ceremony on 18 June. Node-2 was designed and built by Alenia Spazio of Turin, Italy, as part of the Columbus launch barter arrangement between NASA and ESA and a follow-on arrangement between ESA and ASI.

Another of ESA's major contributions to the ISS is delivered ...

Node-2 is an interconnecting module which, when attached to the Destiny laboratory, will allow the addition of a wide range of international elements: Columbus, Japan's Kibo module, the Centrifuge Accommodation Module, Italy's Multi-Purpose Logistics Module, and a Pressurised Mating Adapter that will serve as the normal docking port for the Space Shuttle during its visits to the ISS.

Node-2 will also distribute resources and utilities from the Station Truss and the centralised Station functions, such as power and heat rejection, to those modules.

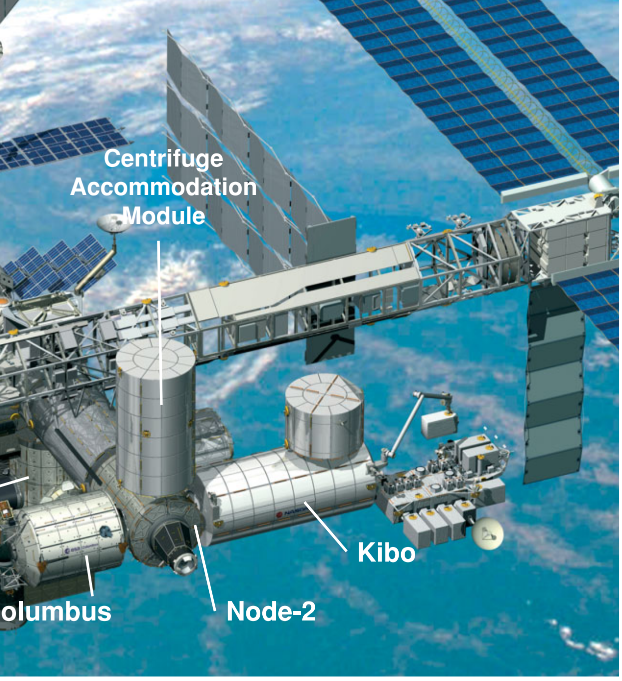
The Integration Process

At the end of summer 2002, the main internal 'building blocks' of Node-2 – the avionics racks, and the four mid-bay and alcove structures – were inserted and connected. By joining these pre-integrated structures, all the functionality required by the Node-2 architecture came to life. The avionics racks include four power converter units and two main computers, while the alcove and mid-bay structures contain the pumps for the active cooling and the cabin fan, heat exchangers and filter for the environmental control system.

After this mechanical build-up, the harnesses were checked end-to-end to make sure that each wire in every bundle and connector was properly routed and undamaged by the integration process. In parallel, all the fluid line connections were tested to make sure that no water, nitrogen or oxygen would leak during testing or operations. Once the connectivity was confirmed, the functional tests could start in earnest.

System Testing

For each building block, the equipment integrated in these structures was turned on,



one at a time, and checked that it worked properly. Then more equipment was turned on and that functional chain checked in full, making sure that all the parameters were within the expected values. Progressively, more functional chains were added, until the whole module's functionality could be checked. This incremental testing began with the power subsystem, followed by the thermal control, data management, life support, and finally the audio and video distribution systems.

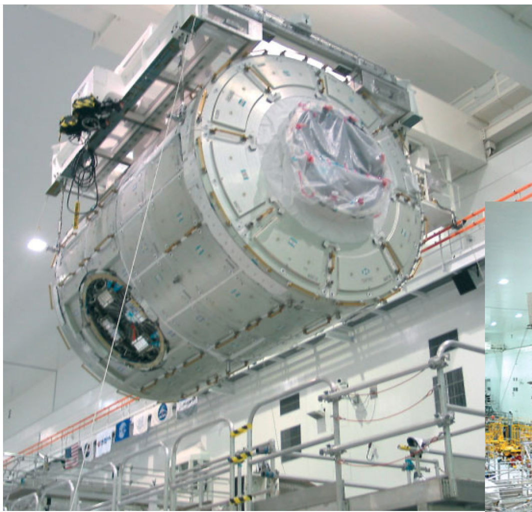
While most of this work was done by Alenia personnel, some of the activities calling for equipment 'external' to Node-2 required support by NASA and Boeing via the Hardware and Software Integration (HSI) test. For this, equipment was brought in to simulate the commands to be given to Node-2 by the NASA Destiny laboratory, already working at the Station, and the thermal loads from neighbouring elements. All the functional paths were thoroughly checked module-to-module to demonstrate that all the interface requirements had been satisfied.

The HSI test was the forerunner of the Multi-Element Integration Test (MEIT) that Node-2 will undergo at KSC in the Space Station Processing Facility (SSPF) over the next few months. In this test, Node-2 will be functionally attached to the Japanese Kibo Flight Unit and the Destiny laboratory emulator and tested in a more complete fashion. By performing the HSI test at Alenia before its formal delivery, confidence has been gained that Node-2 will properly work during the MEIT test and later in orbit.

Like the Centrifuge Accommodation Module, Columbus will not be part of this configuration because it will not be at KSC at that time. The Columbus interfaces to Node-2 and the rest of the ISS will have been verified separately by tests at Astrium in Bremen, Germany, using Node-2/ISS emulators, and finally in the Software Verification Facility at the NASA Johnson Space Center for overall stage verification.

Some Problems Encountered

The functional tests performed so far on Node-2 have been highly successful, but some problems were encountered during less glamorous activities, such as mechanical integration. Difficulties with some US-sourced



Node-2 arrives in the SSPF.

Almost ready for departure from Turin. (Alenia)

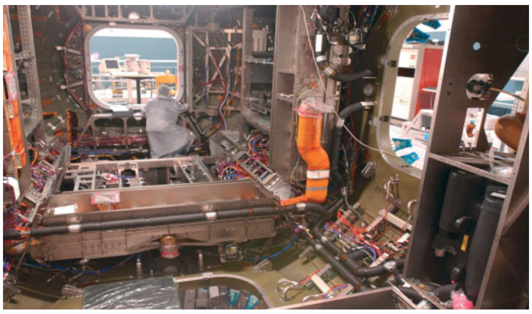
Loading Node-2 aboard the Beluga transporter. (Alenia)

Node-2 Major Capabilities
- regulation and distribution of electrical power to attached elements and internal Node loads (sized for 56 kW);
- active thermal control of coolant water for heat rejection from internal Node equipment and from attached elements;
- temperature, humidity and revitalisation control of cabin air and air exchanged with attached elements;
- atmosphere pressure control during Shuttle transportation;
- distribution lines for cabin air sampling, oxygen, nitrogen, waste water and fuel cell water;
- data acquisition and processing to support power distribution, thermal control and environmental control functions inside the Node, as well as data exchange between Destiny and Node-attached elements. Physical layers comprise 1553, Ethernet, fibres and discrete lines;
- audio and video communications, involving optical fibres, analogue lines and co-axial lines.

Node-3 Major Capabilities
Featuring the same basic Node-2 capabilities, Node-3 manages less power but has additional capabilities:
- on-orbit air pressure and composition control, including carbon dioxide removal;
- oxygen generation, based on a dedicated rack also scarred for future water generation;
- waste and hygiene compartment;
- urine and water processing;
- controlled venting of byproducts from environmental control functions;
- potable water distribution;
- audio and video recording;
- on-orbit reconfiguration of utilities provided to Cupola and MPLM.

equipment, particularly pipe/flex-hose quality and cleanliness, added months to the Node-2 schedule. There was also a significant European industrial dispute that resulted in a change at a late stage of a subcontractor for the internal secondary structure. Such mechanical integration problems became magnified because the Flight Model was being developed without the benefit of a preceding Engineering Model. Even the most sophisticated design tools and experienced draftsmen did not identify all problems related to integration in crowded spaces and tight tolerances. Alenia's dedication and flexibility in overcoming such problems have to be commended not only for having resolved the technical difficulties but also for having done so in the middle of a difficult financial and complicated management situation.

The Acceptance Process
Before its delivery to KSC, the Node-2 design and verification documentation, including all the test results, were thoroughly checked to show the design requirements had been completely satisfied. The Flight Unit was inspected to show compliance to the design documentation and any difference was properly reconciled with the existing paperwork. The build paperwork was examined to make sure that all the integration steps had been properly executed and the crew and relevant quality/safety organisations made sure that each space behind close-out panels – either internal or external – was free of manufacture defects and dangers to the crew, such as sharp edges.



Working on Node-2, September 2002. (Alenia)

Following Delivery
Following the successful inspection that showed Node-2 had travelled from Turin to Cape Canaveral without problems, the Italian space agency ASI (the contractual customer of industry) formally accepted the module from Alenia and transferred ownership to ESA. Simultaneously, ESA transferred ownership to NASA as part fulfilment of the ESA obligations for the Columbus launch barter.

Marking the formal transfer of Node-2 from ESA to NASA, Alan Thirkettle (centre, MSM Development Department) shakes hands with Michael Kostelnik, NASA deputy associate administrator for ISS and Shuttle Programs. At left is Andrea Lorenzoni, ASI's Programme Manager for Node-2.

Node-2 will be in a special test cradle for the next few months. It will undergo a second set of functional tests, and then a final leak test in a vacuum chamber, just before beginning final launch preparations. The launch date, which was to have been February 2004, remains to be settled in the wake of the *Columbia* accident.

Now for Node-3
The successful completion of Node-2 bodes well for the current and future Node-3 work at Alenia. Node-3 will add water processing and oxygen generation for the US segment, avoiding sole dependence on Russia's Zvezda module. Experience accumulated in such a large and complex element as Node-2, in particular in the areas of mechanical design and integration, provides an excellent basis for completing the rest of the programme. ■

Recovering the Science

The Science Repercussions of the *Columbia* and Foton Accidents

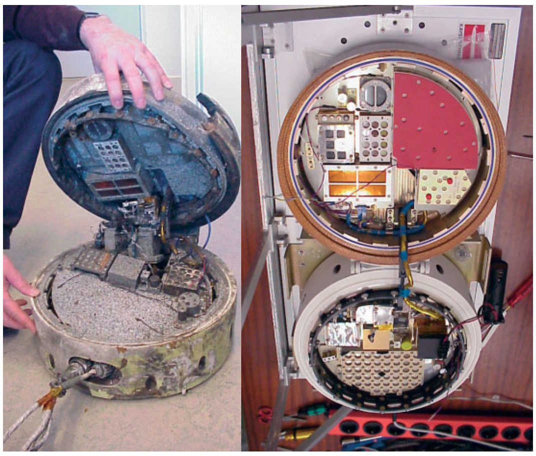
Werner Riesselmann
Utilisation Department,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Werner.Riesselmann@esa.int

Introduction

ESA's microgravity science programme was hit by two significant setbacks within 4 months.

Since Bion-8, in 1987, the Agency has flown life and physical science experiments on Russia's recoverable Bion and Foton capsules. The most recent, Foton-M1, carrying 44 ESA-sponsored experiments (*On Station* #10, September 2002), ended dramatically on 15 October 2002 with the explosion of the Soyuz launcher within seconds of lift-off from the Plesetsk Cosmodrome.

There is a similar and even longer cooperation between ESA and NASA on using the Space Shuttle for microgravity research. The first such flight, STS-9, took place in 1983 with Shuttle *Columbia* carrying Spacelab-1. ESA's first astronaut, Ulf Merbold, supported a large and highly diverse set of international payloads. The latest, STS-107, again used *Columbia*, with 37 ESA-sponsored experiments (*On Station* #5, March 2001). Tragically, it ended on 1 February 2003 with the loss of the seven astronauts after a near-perfect mission. *Columbia* disintegrated during reentry, less than 15 minutes before its scheduled landing at the Kennedy Space Center.



Biopan survived the Foton-M1 explosion relatively intact (left). At right is the pre-flight view.

Foton-M1

The development, manufacture and qualification of the 44 Foton-M1 experiments proceeded smoothly according to schedule. Final payload preparation and testing took place in the month before launch, including integration of sensitive biological samples within the last 3 days. Soyuz cleared the pad but rose to only a few hundred metres before the engines were shut down. It hit the ground and exploded less than 1000 m from the visitors viewing the launch. The report of the Russian State Investigation Commission concluded that a 'foreign metallic object' caused a turbopump to fail, cutting the engine propellant flow.

How can European researchers recover from the losses of two major sets of science payloads?

The remains of a Biofilter from Foton-M1.

Remains of FluidPac.

After the accident, ESA began to look at reflying the experiments. An inventory of engineering spares and qualification models was made, and the feasibility of modifying, upgrading, refurbishing or even rebuilding the facilities was investigated. The financing was also assessed. The results were positive and so discussions are underway with Rosaviakosmos on a Foton-M2 mission devoted to flying Foton-M1 experiments plus some new ones. The status of the experiments is:

Kalpana Chawla works in the Spacehab research module, with Biobox to her left. (NASA)

Laurel Clark works with the Biopack glovebox. Rick Husband is behind. (NASA)

- the three Outreach/Student experiments will fly soon on the two Soyuz Taxi missions to the ISS in October 2003 and April 2004;
- CNES has no IBIS model that could be upgraded and does not plan a rebuild. Some of the 8 experiments might use the new Kubik facility;
- 'Favorite' (Fixed Alkaline Vapour Oxygen Reclamation In-flight Technology Experiment) is an ESA demonstration experiment for advanced life support technology. It is under development.
- Polizon is a Russian furnace that can sequentially process 11 material science experiments; 6 will be cooperative with ESA.

The other payloads are repeats from Foton-M1:
- FluidPac, 4 fluid physics experiments;
- TeleSupport, assists FluidPac, Agat, Favorite and Polizon;
- Biopan, 9 experiments in exobiology and radiation exposure;
- Agat (DLR), 6 experiments from DLR & ESA on diffusion coefficient measurements;
- Stone, 2 meteoritic reentry experiments;
- Aquacells (DLR), an experiment in biology of water microorganisms;
- Keramik (DLR), a reentry technology experiment;
- SCCO (Soret Coefficients in Crude Oil), 2 experiments on diffusion effects in crude oil;
- Autonomous, 3 experiments in biology (Biofilter, Photo-II, Rado-2).

The negotiations with Rosaviakasmos indicate that Foton-M2 will fly in spring 2005 with a payload of 400 kg from ESA. If this can be achieved, then only 4 IBIS experiments would still be waiting for reflight opportunities.

STS-107/*Columbia* Payloads

The seven ESA multi-user facilities for STS-107 were carried either in the mid-deck of *Columbia* or in the Research Double Module of Spacehab Inc. Some had flown on earlier missions:
- Advanced Protein Crystallisation Facility (APCF), 8 experiments;
- Biobox, 4 experiments;
- Facility for Absorption and Surface Tension studies (FAST), 3 experiments;

Others were developed specifically for STS-107:
- Advanced Respiratory Monitoring System (ARMS), 8 experiments;
- Biopack, 8 experiments;
- COM2PLEX, Combined 2-Phase Loop Experiment with three different loop heat pipes;
- European Research in Space and Terrestrial Osteoporosis (ERISTO), 2 experiments.

The STS-107 mission had to face serious delays over about 2 years until its launch on 16 January 2003. Payload integration into Spacehab and *Columbia* was consequently stretched over more than a year, and all testing was performed individually for each instrument. Around last Christmas, the first investigators started to prepare their biological samples in the laboratories of the Florida Institute of Technology in Melbourne, some 50 km south of KSC. In the last week, about 100 experts prepared the samples for Biobox, Biopack and ERISTO, the flight operations and the logistics for late hand-over of sensitive samples and facilities to Spacehab/NASA. This hand-over for late installation of APCF, Biobox, Biopack, ERISTO and FAST into the Shuttle on the pad took place between 18-40 hours before launch.

Biobox was the first payload to activate itself 8.5 min after lift-off when its accelerometer sensed good microgravity conditions. Biobox continued to process its four experiments perfectly throughout the mission.

Other facilities were activated as planned by the crew in the following hours and days. APCF, COM2PLEX and FAST required no or minimum crew attention because they worked fully automatically or under close control of the ESA ground teams. The three facilities performed flawlessly and the ground teams of COM2PLEX and FAST were excited about the quality and amount of telemetry and video data being received on the ground.

Biopack required significant crew time for the handling of experiment containers including their transfers between incubator, cooler, freezer, portable glovebox and Passive Thermal Conditioning Unit. Until flight day 7, Biopack performed very well and three experiments were fully completed. From then on, it could not be used in high-power consumption (360 W) mode because the air-cooling loop was blocked by debris. Later, Biopack was operated in a workaround mode with minimum power; three experiments were processed this way.

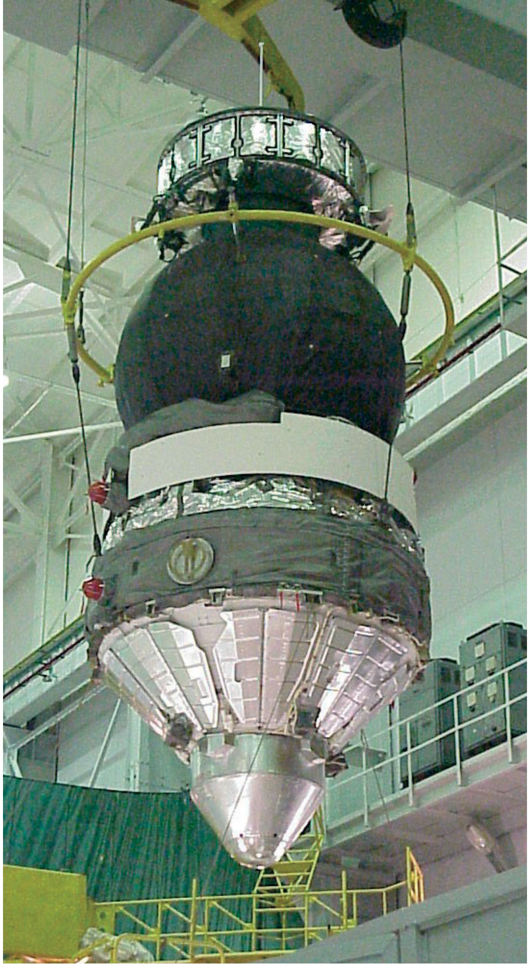
ARMS performed well and very good data were received on the ground. Experiment processing was grouped in three sessions: early in the flight, in the middle and at the end, tracking the crew's progressive adaptation to microgravity. Each session involved the same four astronauts.

ERISTO's supply of nutrients to bioreactors with human bone cells had to be manually stimulated once per day by the astronauts after initial activation. It performed perfectly.

Recovery Plan for STS-107 Experiments

For the group of three biology facilities (Biobox, Biopack and ERISTO) and APCF, there are no scientific results because no samples survived. For ARMS, COM2PLEX and FAST, plenty of data are awaiting analysis.

ESA science aboard STS-107: Biobox at bottom left, and APCF at top left, on the Spacehab aft bulkhead. (NASA)


Foton-M1 ready for flight.

In a meeting with most European STS-107 investigators on 8-9 April 2003, the needs and options for reflying their lost experiments were discussed. As it is unlikely that NASA will make a dedicated Shuttle science flight available in the foreseeable future, other opportunities were explored.

Biobox was originally built for and flown on Bion and Foton. Building a new Biobox for flight on a Foton-M3 is the first choice. As APCF requires astronaut support, and as a new generation of protein crystallisation facilities is available, investigators agreed to use the Granada Crystallisation Facility (GCF) and ProMISS on Soyuz Taxi flights or on Foton.

It would be difficult to adapt ERISTO for automatic operation, as required by Foton, so we intend to search for a reflight on the Shuttle, either through Spacehab Inc. or NASA. Biopack is also crew-tended but it would require 4-6 Shuttle mid-deck lockers. We plan therefore to assess using the Kubik or Biobox facilities on Foton-M3 for Biopack experiments.

It should be possible to satisfy most STS-107 investigators before the end of 2006 via the envisaged Foton-M3. This is a convincing argument to continue negotiations with Rosaviakosmos for two Foton-M flights in spring 2005 and in autumn 2006.

MELFI Ready for Launch

Another ESA rack is prepared for the ISS

Jesus Jimenez[1] & Aldo Petrivelli[2]
[1]MELFI Project Manager; [2]MELFI Payload Integration & Operation Manager, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Jesus.Jimenez@esa.int; Aldo.Petrivelli@esa.int

Introduction

The Minus Eighty degrees Laboratory Freezer for the ISS (MELFI) successfully completed its test campaign at the Kennedy Space Center (KSC) in October 2002. The first flight unit (FU1) is manifested for the Multi-Purpose Logistics Module (MPLM) on Shuttle flight STS-114, as part of the first ISS Utilization Logistics Flight (ULF-1). STS-114 was set to fly in the first week of March 2003 but, following the loss of *Columbia* during STS-107 in February, the Shuttle fleet was grounded. MELFI is still inside the MPLM ready to resume the 'countdown' as soon as the Columbia Accident Investigation Board completes its investigations.

MELFI is ready to provide the ISS with permanent cold storage, including the launch and return of frozen samples ...

MELFI FU1 at KSC ready for integration in the MPLM. An acoustic blanket is installed on the upper part.

The MELFI Freezer and its Mission

MELFI is an ESA-provided facility rack with four independent refrigerated volumes (the dewars) for storage and fast freezing of almost anything that fits the shape of the cold cavity. The temperature in each dewar can be set to three different independent modes (+4, –20, –80°C), and the set point can be as low as –95°C. A detailed description of MELFI and its capabilities can be found in *ESA Bulletin* #109 (February 2002).

MELFI's mission is to carry cold or frozen cargo to the ISS, active inside the MPLM/Shuttle, stay aboard the Station normally for 2 years, and return cold cargo to ground. For ULF-1, MELFI FU1 will fly passive, because the MPLM active version is not yet operational. In this first mission, MELFI will be transferred to Destiny.

The MELFI Verification Programme

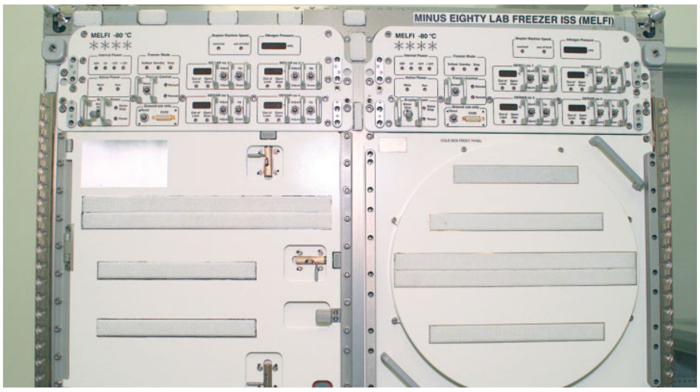
MELFI was designed by a European industrial consortium (led by Astrium SAS in Toulouse), integrated in a NASDA-provided International Standard Payload Rack (ISPR) and it will be operated in the US segment of the ISS. These multiple external interfaces have added complexity to the already-demanding verification of the MELFI system. In addition, the lack in Europe of a suitable Destiny interface simulator required the development by ESA of the Test Equipment for Payload Development (TEPAD). The TEPAD water servicer and power supply emulator, along with the NASA-provided Suitcase Test Emulator for Payloads (STEP), formed the bench for testing the Destiny interfaces in Europe. The test set-up was complemented by dedicated Ground Support Equipment (GSE) for data acquisition and facility control, developed by Astrium. Although providing high fidelity simulators, this GSE is not the same as the actual ISS interface, so the verification programme had to secure a MELFI design compatible with the ISS interfaces by:

Testing in Europe:

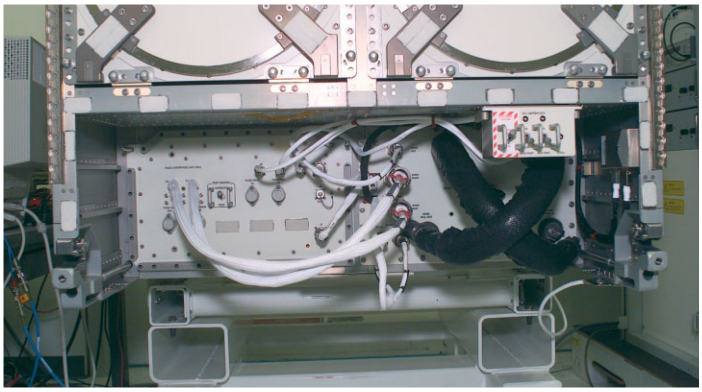
- validation of the TEPAD interface simulators, by comparison of the detailed design and performances between the TEPAD equipment and ISS test facilities in the USA;
- early software validation, through interface testing at subsystem level in the ISS Software Integration Laboratory at the NASA Johnson Space Center;
- extensive system performance and interface tests in Europe, using the TEPAD/STEP test set-up.

Final verification at KSC:

- final interface verification in the Payload Checkout Unit (PRCU). This is the KSC off-line testing;



The rack upper part, with the acoustic blanket removed. Top: the two electronic units (spare on the left and active on the right). Below: the stowage compartment (with a spare machine inside and the MELFI tools) and the Cold Box cover.



MELFI's lower part, with the tissue cover removed. The umbilicals are in the parked launch configuration.

– mission end-to-end verification in the Payload Test Control System (PTCS). This is the KSC on-line testing.

Finally, the project had to follow a major evolution in Destiny's interface definition and verification requirements. This significantly stretched the engineering effort, with associated financial implications. Nevertheless, the budget has been kept within the original constraints.

Highlights of MELFI Verification

Verifying the new technologies developed for MELFI was much more challenging than expected at the beginning of the project:

– environmental qualification of all equipment for 15 launches. The qualification of the Brayton subsystem (MELFI's cooling source) was particularly challenging;
– life-endurance verification of a new cooling engine (turbo-machine running at 90 000 rpm with a minimum of 2 years' continuous operations);
– tuning of the brushless sensorless technology for the Brayton motor, especially the start phase.

Verifying the structural design is another important achievement – MELFI stretches the structural capabilities of the ISPR to the limits. MELFI is the heaviest payload certified for the ISS (almost 800 kg in the heaviest launch configuration). MELFI has been used as the test case for establishing the methodology for the structural integration and verification of payloads using the NASDA ISPR as the payload primary structure. Through MELFI, ESA has developed the methodology that is being applied to the structural verification of the other Agency payloads using the NASDA rack.

Verification of the thermal performances required a significant analytical and test effort. The dewar cold cavity is passively cooled (conduction and radiation) but, because there is no convection in zero gravity, the thermal behaviour in space differs from that on the ground. Also, thermal performance on Earth depends on the rack orientation. This peculiar behaviour was assessed to confirm that the required mission profile can be achieved flying active in the MPLM (different rack orientations are possible on the launch pad, when the Shuttle is vertical). System thermal testing demanded long tests – in many cases requiring the attendance of a test conductor 24 hours a day. Another challenge was the acoustic insulation to meet the very demanding acoustic noise limits of the ISS (NC40).

MELFI's flight software successfully interfaces with the Destiny and MPLM payload computers. The commands to modify almost any parameter of the MELFI control laws will be a precious tool for fine-tuning MELFI's thermal regulation in orbit.

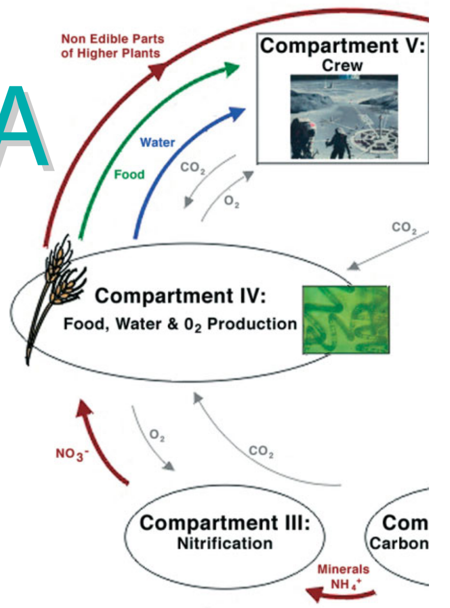
Owing to the late availability of the flight Brayton subsystem, FU1 had to be completely disassembled and reassembled at KSC in a record time of only 3 weeks. Eventually, the final verification tests in the PRCU and PTCS were completed without a hitch.

ESA has agreed with NASA and NASDA the extension of the MELFI verification programme to demonstrate compatibility with the Kibo Japanese Experiment Module (JEM). During the final verification tests in the PRCU, the test facilities were configured to simulate the Kibo interfaces. These preliminary tests indicate that, with some minor software changes, MELFI can operate in Kibo. A more thorough verification is under way, with the objective of fully implementing this capability for the delivery of MELFI FU2.

More MELFI Units to Come

MELFI FU2 and FU3 are now undergoing rack-level integration before their test campaigns in Europe. It is expected that FU2, for NASDA, and FU 3, for NASA, will be at KSC by February 2004 for their final acceptance testing. ■

Living with MELISSA



Europe's Project for Bioregenerative Life Support

Mónica Lobo & Christophe Lasseur
Thermal and Environmental Control Section, Directorate of Technical and Operational Support, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Monica.Lobo@esa.int; Christophe.Lasseur@esa.int

Introduction

Supplying all the food, oxygen and water from Earth for long space missions is clearly prohibitive. For example, a 6-man crew on a 3-year trip to Mars would require around 33 t, plus handling of the waste products. Developing a regenerative life-support system is obviously an imperative.

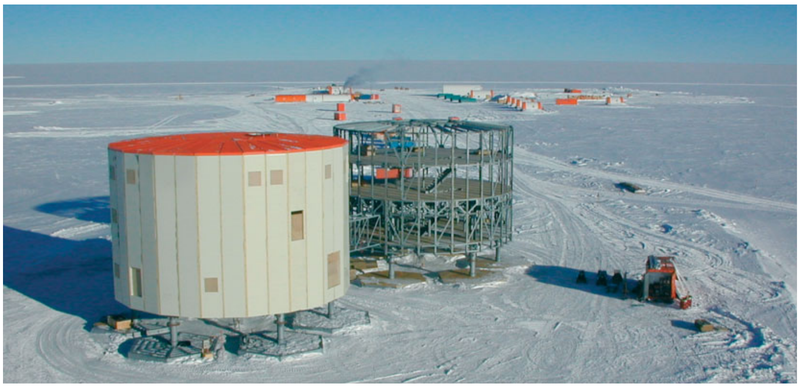
Future space activities call for a radically new approach to life support ...

MELISSA

The goal of MELISSA (Micro-Ecological Life Support System Alternative) is to recover edible biomass from waste and carbon dioxide using light as the major energy source (photosynthesis). MELISSA is composed of five compartments colonised by thermophilic anoxygenic bacteria, photoheterotrophic bacteria, nitrifying bacteria, photosynthetic bacteria, higher plants and the crew. The very high level of safety requirements for manned space missions means that the MELISSA ecosystem is compartmentalised.

The liquefying Compartment (#I) is the first step in the cycle. It biodegrades the crew wastes into basically volatile fatty acids, ammonia and minerals. The carbon dioxide generated in this compartment is supplied to Compartment IV (photosynthesis). The volatile fatty acids and ammonia produced during the anaerobic fermentation process are fed to Compartment II, where the inorganic carbon is transformed into organic carbon sources. The nitrifying Compartment III serves mainly to convert the ammonia from Compartment II into nitrates. Nitrate is the most suitable nitrogen source for Compartment IVb (higher plants). Compartment IV is responsible for removing carbon dioxide, generating edible biomass as the food supply, recovering water and regenerating oxygen for the crew. It is divided into the photoautotrophic bacteria (*Arthrospira platensis*) Compartment IVa and the higher-plant Compartment IVb.

The Concordia base in Antarctica will use MELISSA technology for recycling. (S. Drapeau, IPEV)

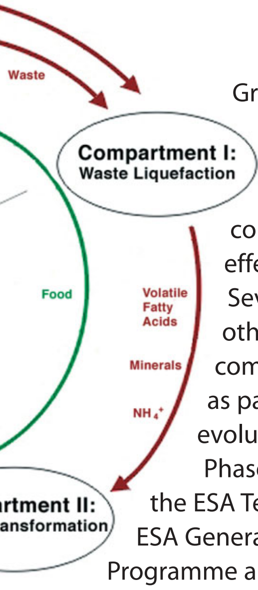


Phase1: Terrestrial Demonstration

Each compartment in the loop is analysed separately and treated as a chemical process. The mass balance is mathematically described and validated with experimental results from batch and continuous cultures. So far, the six most heavily-used chemical elements (C, H, N, O, S, P) have been taken into account, but others (Na, K, Mg, …) will be progressively investigated.

The integration and testing of the results obtained by the international team are being performed in the MELISSA Pilot Plant at the Universitat Autònoma de Barcelona, an ESA external laboratory). In 2000, Compartments III and IV were connected at the Pilot scale; in 2001, Compartments II, III and IV were connected at the bench level for 1000 h.

After 14 years of research, the feasibility of each MELISSA compartment has been demonstrated and a recycling level of better than 70% has been shown by simulation.



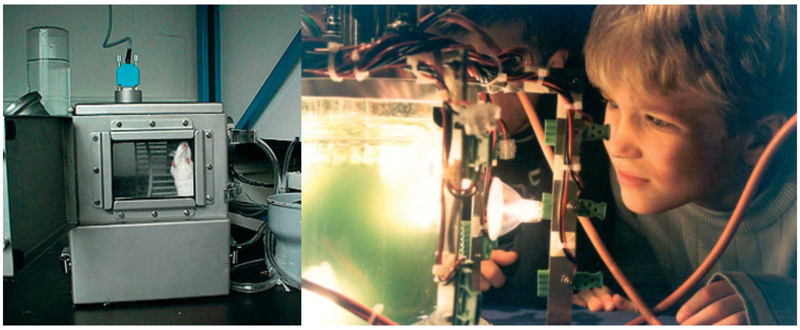
Greater recycling will clearly depend on many factors: interfaces with other subsystems, mission configuration and psychological effects such as the quality of diet. Several studies are considering other biological processes and/or complementary technologies, such as pathogen detection, genetic evolution and new sensors.

Phase 1 is funded mainly through the ESA Technology Research Programme, ESA General Support Technology Programme and national budgets.

Phase 2: Preliminary Flight Experiments
In designing any bioregenerative system we must quantify the effects of the space environment on biological processes. MASK (Microgravity Analysis of Spirulina Kinetics), BIORAT, FEMME (First Extraterrestrial Man Made Ecosystem) and MESSAGE (Microbial Experiment in Space Station About Gene Expression) are under way to qualify and quantify these space effects. BIORAT, currently in Phase-A/B, has already used a mouse to demonstrate MELISSA's predictive control and the recycling of oxygen/carbon dioxide. MESSAGE flew on the Belgian Odissea mission in November 2002 to compare the gene expression of microorganisms on Earth and in space. Phase 2 is being performed in collaboration with the Utilisation Department of D/MSM within, for example, EMIR and Prodex.

Phase 3: Space Adaptation
This phase recently began to adapt the technologies developed in Phase 1 taking into account the constraints imposed by life support hardware. A system study into reliability and dependability and to identify critical space technologies began in 2001. Technical support is also being given to a D/MSM study into the feasibility of a space greenhouse. The AURORA study into phase separation for gas management will begin soon.

Phase 4: Technology Transfer
The combination of advanced biotechnology processes plus the stringent requirements of space missions have resulted in a number of innovative solutions, producing scientific knowledge and industrial applications, with the support of the ESA Technology Transfer Office. Concrete examples of MELISSA technology spin-offs include:



BIORAT has already satisfied the oxygen needs of a mouse.

- MELISSA's nitrifying compartment has led to a new bacterial agent in collaboration with the Vivendi company. More than 1 500 000 m^3 of wastewater are being treated daily in more than 100 towns;
- in order to quantify immobilised biomass and/or biomass within sludges, a new biomass sensor has been developed with the NTE company. Frexeinet, a world leader in sparkling wine, is using 20 of these sensors on line. The market has been estimated at 1000 units/year;
- based on Compartment I, a 'black-water' recycling system is under construction for the Concordia research base in Antarctica.

MELISSA's objectives and results continue to attract public attention – journals, magazines, web, radio and TV. There are also educational activities. More information can be found at *http://www.estec.esa.nl/ecls/default.html*

Conclusion
MELISSA is a multidisciplinary project with the main goal of developing a regenerative life-support system for long-duration manned space missions and manned bases. So far, its feasibility has been demonstrated and its recycling levels are promising.

MELISSA: An International Collaboration
The MELISSA project began in 1989. A collaboration, established through a Memorandum of Understanding and managed by ESA, involves several independent organisations: IBP (Institut de Biotechnologie de Plantes), Orsay (F), University of Ghent (B), EPAS (Eco Process Assistance) (B), UBP (Université Blaise Pascal, F), VITO (Vlaamse Instelling voor Technologisch Onderzoek, B), SCK (StudienCentrum voor Kernenergie, B), ADERSA (Association pour le Developpement de l'Enseignement et de la Recherche en Systématique Appliquee, F), UAB (Universitat Autónoma de Barcelona, E) and UOG (University of Guelph, CND). It is co-funded by ESA, the MELISSA partners, and Belgian (Services du Premier Ministre Affaires Scientifiques Techniques et Culturelles), Spanish (Comissio Interdepartamental de Recerca I Innovacio Tecnologica and Centro de Investigacion Cientifica Y Tecnologica) and Canadian (Center for Research in Earth and Space Technology, Canadian Space Agency) authorities. There are also many collaborations with companies and research centres in Germany, Ireland, The Netherlands, USA and Russia.

Expedition Doctors

Medical Support for the Expedition-5 Crew

Filippo Castrucci, MD
Flight Surgeon, MSM-AM,
Europan Astronaut Centre Integrated Team, Cologne, Germany
Email: Filippo.Castrucci@esa.int

Expedition-5 departs from its home in space. (NASA)

ESA's first ISS Flight Surgeon considers the valuable lessons learned during Expedition-5 ...

Introduction

The Expedition-5 crew of Commander Valeri Korzun and Flight Engineers Peggy Whitson and Sergei Treschev returned to Earth in December 2002 after logging 184 days aboard the International Space Station (ISS). As promised in my first article (*On Station* June 2002, pp.6-7), I am now reporting back on my experience as the Deputy Crew Surgeon for Expedition-5 in the heart of the Blue Flight Control Room, the ISS Mission Control Room (MCC-H) at the NASA Johnson Space Center (JSC) in Houston, Texas. There, I lived and worked through long days and nights, alongside American and Russian colleagues, during the 6-month mission, with the goal of seeing the crew back safe and healthy.

A valuable lesson I learned during this mission is that, with the Station expanding to encompass new cultures and complexities, the challenge is to take advantage as early as possible of any contribution from the Partners, regardless of the assembly sequence. By assigning an ESA Surgeon to an ISS Expedition before the launch of Europe's Columbus module, the ISS medical community took a coherent step in that direction. Optimally blending the capabilities of all the Partners and extending their expertise in real-time operations through early involvement in routine mission support will help to guarantee the success of the ISS programme.

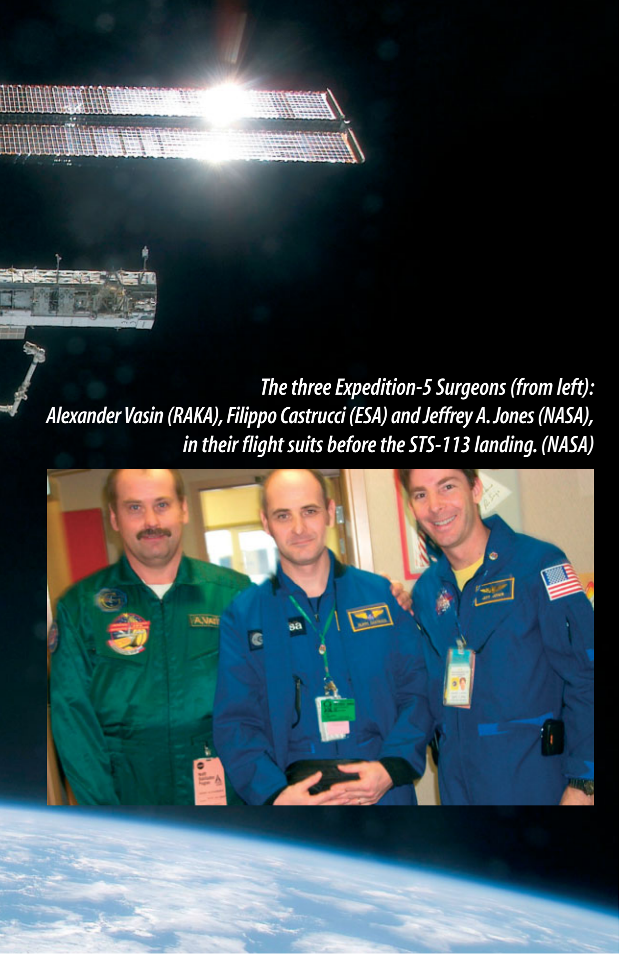
Integration and Flexibility

During my time in MCC-H, I learned that an effective ground control team should closely reflect the technical, human and cultural characteristics and peculiarities of the crew in space.

The goal is to identify and blend the unique resources and capabilities that each Partner can contribute, into one common Plan. This can be achieved by facilitating diverse, potentially redundant, concepts of operations and multilateral control, adding the flexibility to respond to routine and contingency alike. Following the loss of *Columbia*, switching to Soyuz/Progress-only operations has safely maintained the ISS in orbit. The absence of this flexibility and redundancy would have crippled the ISS, endangered the crew and brought the programme to a halt.

Redundancy and flexibility also proved decisive in the temporary hand-over of all mission control activities to the Mission Control Centre in Moscow (MCC-M) when Hurricane Lili forced evacuation of JSC last autumn. MCC-M had been maintaining its control and command capabilities all along, so Expedition-5 lived through a potentially critical situation with minimal distress, both in space and on the ground.

As the ISS multicultural crew and their health are the Medical Team's prime responsibility, the medical support for ISS has from the beginning faced the need to apply flexibility to the diverse needs and expectations of each crewmember, while maintaining a unified and integrated



The three Expedition-5 Surgeons (from left): Alexander Vasin (RAKA), Filippo Castrucci (ESA) and Jeffrey A. Jones (NASA), in their flight suits before the STS-113 landing. (NASA)

programme. Although such a programme is still in the making, a lot has been already achieved by working side-by-side from day 1 of Expedition-1, knowing and accepting each other's requirements.

During Expedition-5, NASA's Dr. Jeffrey A. Jones, our Expedition Lead Crew Surgeon, RAKA's Dr. Alexander Vasin, Russian Partner Flight Surgeon, and I worked together, often sitting at the same console, addressing and responding together to different issues in real-time. This helped us to experience not only each other's method of solving problems, but also our cultural and individual peculiarities.

During all this, the US, Russian and ESA flags standing on top of our Integrated Medical Group console were a statement of the resolve to integrate our efforts.

Multilateral Medical Control: a Successful Test

This resolve stood the test during Frank De Winne's Odissea Mission last November. NASA, RAKA and ESA medical teams used the opportunity to refine the multilateral concept of operations. This was done first by planning for the mission, months before, in Houston, in Moscow and over communication loops, and then by working together, real-time, during the mission. The ISS Surgeons were able to address toxicology and payload issues through real-time information and decisions from the ESA Medical Operations Console in the European Astronaut Centre (EAC), who, in turn, coordinated with the ESA Payloads engineer. This ability to communicate and solve problems allowed potentially disruptive experiments to be performed during the flight with minor impact or concern to the crew. Without this integration, activities would have been deleted, with loss of science and unproductive hindsight discussions.

The assessment of this experience will be valuable to everyone in preparing for shared and multilateral ISS operations in the future. This is especially true for ESA Medical Operations, which had the unique opportunity to experience the requirements for real-time mission support from their Control Room at EAC, to the extent of holding a private medical conference with the ESA astronaut onboard.

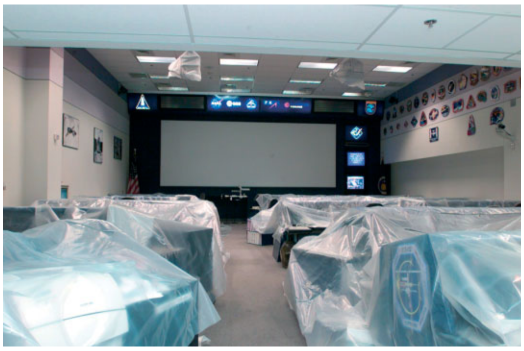
Expedition-5 and Taxi Flight crews during the Odissea Mission. (NASA)

The Rôle of the Surgeon

Although going into this mission I was aware of the value and need for integrated medical support, I soon learned that they were only the tip of the iceberg.

With Surgeon responsibilities stretching from caring for the health of the crew to protecting their rest time, monitoring the environment and taking care of the health-related hardware, I almost immediately realised how this medical team was called upon on a daily basis to deal with issues that would not normally be perceived as medical. However, taking the crew as the most valuable and integrated system on-board, and understanding how all the systems interface, it is obvious that something affecting one system is also likely to affect the crew. This might be additional tasks for them, or real health hazards.

Activities in Mission Control are highly integrated. Most are engineering tasks with the crew as part of the equation. As the flight controllers in MCC have comparable backgrounds and common objectives, they always reach solutions that make good operational sense. However, although the crew is a significant component of the equation, its status is not fully known to the ground team, with the exception of the Surgeon. Depending on the trust he or she is able to build with the crew, the Surgeon has a better insight into the crew's ability to cope and perform at that particular time. Thus, it is the Surgeon's duty to sense, value and question the urgency and priorities of any task the crew is asked to perform, searching for the rationale and balancing the pros and cons. If there is a concern with the crew's ability to carry out the task, it is the Surgeon's responsibility to negotiate with the control team and reach a viable compromise.



ISS Control Room In Houston geared up to withstand Hurricane Lili last autumn. (NASA)

For the same reason, the Flight Surgeon closely monitors the level of planned activities for an Expedition and the balance between workload and time off. During Expedition-5, this balance was established early in pre-flight planning, and it proved critical for the crew's good performance. As this balance is very crew-specific, its correct tuning sets the overall pace of the mission. However, besides the agreed work/rest cycles (8.5 h sleep, 6.5 h work, 2.5 h exercise), it is not uncommon that unscheduled duties arising from unexpected events are proposed at short notice, via the Planning Product Change Request (PPCR). These extra duties often breach the workday. The Surgeon is part of the decision-making process, approving or disapproving the PPCR and mediating with the Flight Director, as the ultimate authority.

Life aboard the Station is a daily regimen and priorities may be quickly rearranged by events, demanding flexibility on the part of the schedule and the people. There are mechanisms to buffer impacts on the crew. The task-list option, which our crew preferred, allowed the ground to move certain tasks in and out of the task-list, depending on the urgency, letting the crew manage their time more effectively. This is a personal preference, and not all crews choose this option.

Physical exercise is another critical daily activity subject to personal preference. Crews view it as a necessary therapy to ameliorate the negative effects of microgravity. However, some struggle through it, while others, as with our crew, actually enjoy it and look forward to this time of day to unwind. As exercise is crucial to the crew's well-being, it is always on the Surgeon's radar screen.

The Flight Surgeon keeps the Station environment constantly under watch, because the bubble of air filling the ISS cabin is vital for survival. A malfunction in a carbon dioxide (CO_2) scrubbing device, if not quickly resolved, will eventually lead to accumulation of the gas. The Surgeon will be called to mediate between the operational requests from the rest of the team to maintain critical activities as usual, while keeping the CO_2 within safe margins. In doing so, the Surgeon needs to have a clear understanding of the mission priorities versus the crew health requirements. With elevated CO_2, crew exercise is normally reduced or cancelled. However, towards the end of a mission, when exercise has priority to prepare the astronauts for return to Earth, the Surgeon will ask to have other CO_2-producing activities cancelled or other CO_2-scrubbing means used, before affecting exercise time. Often, these decisions prompt discussions among the flight controllers, and the Surgeon may have to raise the concerns at the ISS Programme level to find a resolution.

Similarly, although a malfunctioning exercise device is an engineering issue, it also implies that the crew will not be able to perform a specific exercise during the time the device is off-line, affecting their physical counter-measures programme and, eventually, their health. The Surgeon's duty is to coordinate a plan to find alternate means of exercise that maintains the crew's well-being and regains the lost exercise capability. During our Expedition, this was an excruciating task, as all of the exercise devices malfunctioned at one time or another. Since exercise hardware falls within the Medical Science domain, we had to negotiate at Programme level last-minute deliveries of spares and new hardware on Progress, Shuttle and Soyuz flights.

Even for activities that are clearly in the medical domain, such as the private medical conferences and the periodical health and fitness assessments, the Surgeon relies on technology, communications and the onboard Crew Medical Officer (CMO) to an extent rarely experienced on Earth. The CMO is an Expedition crewmember but not necessarily a medical doctor, and lends his/her ears, eyes, hands and judgement to the Surgeon to make diagnoses and provide cures.

During Expedition-5, a Specialist and the Surgeon in MCC-H tested the capability to perform remote ultrasonography on-board by guiding the CMO through the scanning of major internal organs. The CMO successfully acquired and downlinked quality still and video images. This provides the Surgeon with a valuable diagnostic tool and the capability for more specific medical treatment.

The CMO's pre-flight training and in-flight maintenance of proficiency are among the Surgeon's prime responsibilities, and essential for safely conducting the flight.

The Behavioral Health and Performance Group, part of the Surgeon's team, is responsible for the psychological support and for keeping astronauts and families in contact. The Expedition Psychologist carries out periodical psychological conferences with the crew and reports back to the Surgeon with his/her recommendations. Every weekend at least, this Group, with the help of the Biomedical Engineers, schedules time for the astronauts and families to talk and see each other's family on live video. Generally, families come to the control centres for the video/audio link. During our Expedition, we were successful in having a voice/video connection with the astronaut's families at home and also with the European Astronaut Centre, when one family member was in Cologne attending a conference.

End of Mission and Post-flight

Post-flight activities are probably the most amazing time for the crew, and they provided a phenomenal learning experience for me. Having been away for so long in a unique environment, the first few hours after landing generate a mix of excitement and dismay for the crew. The hard reality of gravity hits everyone, albeit to different degrees. As debilitating as it may seem at first, all crews regain their bearings so quickly that the gross recovery can be measured in hours and days, rather than in weeks and months. This confirms both significant improvements in the in-flight countermeasures and the discipline of the crews in following them. Good all-round physical condition at landing boosts the effectiveness of post-flight rehabilitation. In most cases, over a 45-day period, the astronauts gradually but surely cope with gravity and go back to driving a car, flying an aircraft and enjoying a normal life.

NASA Administrator Sean O'Keefe (5th from left) rewards the Expedition-5 Medical Operations Team. The author is 4th from left. (NASA)

Conclusion

The rôle of a Flight Surgeon, in or out of a control room, should not be compared with that of a doctor in a hospital or office. In most cases, the Flight Surgeon is not dealing with sick individuals, but with healthy ones performing an extreme profession in an extreme and unforgiving environment.
I learned that the Flight Surgeon hopes for the best, but prepares for the worst. The control room is our vantage point, offering the insight and situational awareness of the flight and the flight team. It keeps us abreast of events that may require our intervention at some point.

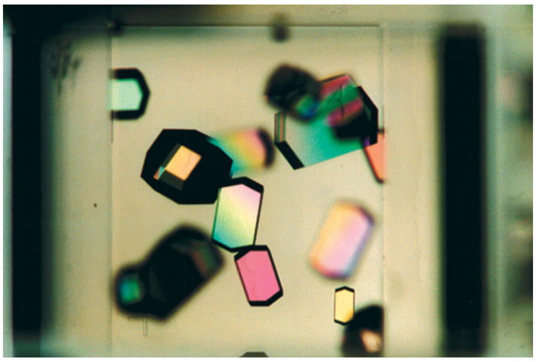
On a personal note, I am extremely satisfied with this experience. I deeply appreciated the considerable level of confidence and support that ESA and DLR gave me. It was also impressive how the medical communities of NASA, RAKA, CSA, NASDA and ESA supported this further step in integration and how they welcomed me as part of the team, with all the obligations, responsibilities and recognition. But, above all, my gratitude goes to my family, because their ability to assume new tasks and responsibilities and to keep our life on track, gave me peace of mind and allowed me to stay focused and motivated on the mission and its objectives.

By better preparing our team today, we will be an integral part of the larger team tomorrow. We have helped to pave the way for the first European on an Expedition crew. He will be able to preserve his identity while enjoying the diversity and capturing a whole new array of opportunities in an ever-developing and fascinating endeavour.

Crystal-Clear Vision

The Protein Crystallisation Diagnostics Facility

Vladimir Pletser
Microgravity Projects Division, Utilisation Department,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Vladimir.Pletser@esa.int



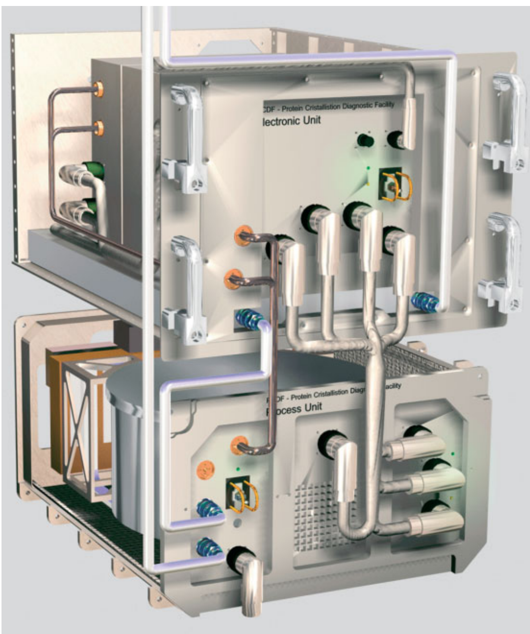
Crystals grown on APCF during the Spacehab/STS-95 mission in October 1998. (ESA)

A new ESA space facility will help to reveal the secrets of biological molecules ...

Introduction

The weightless conditions in orbit have been exploited over the last 20 years for growing the large crystals of biological macromolecules required to expose their structures and understand their functions. So far, the facilities have focused on growing crystals for analysis *after* flight. But, now, ESA's Protein Crystallisation Diagnostics Facility (PCDF), developed by an industrial consortium headed by Astrium, will allow studies *during* flight. With it, we will witness the crystallisation processes of biological macromolecules over long periods in microgravity using advanced diagnostics methods, including video microscopy, dynamic light scattering and Mach-Zehnder interferometry.

The earlier Advanced Protein Crystallisation Facility (APCF), developed by ESA in 1989-92, flew seven times on various Spacelab, Spacehab and ISS missions. Of the 48 reactors, ten could be observed with a CCD camera for recording motions or growth of forming crystals. After several flights, a Mach-Zehnder interferometer was added to observe the crystal growth process in five reactors as well as to measure changes in the refractive index, which relate to concentration gradients caused by diffusion or residual convection in the protein chamber. Later, new reactors were developed with extended protein chambers to exploit the self-optimisation feature of the counter-diffusion technique, and reactors for observations along two orthogonal directions to allow 3-D monitoring of the motions of freely growing protein crystals.

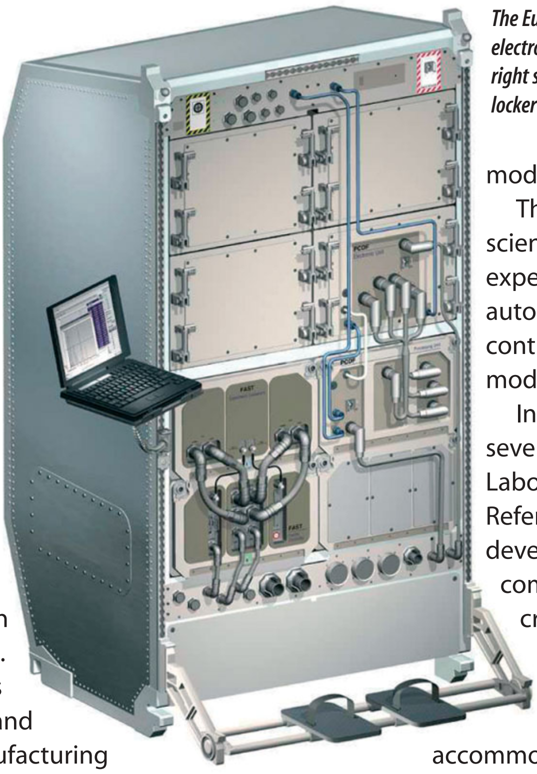


The PCDF electronic (top) and process (bottom) units. The process chamber can be seen behind the process unit front panel. (Astrium)

Based on this APCF experience, scientists realised they needed a new facility better tailored to understanding and characterising the optimum conditions of crystallisation and crystal growth processes with advanced diagnostics.

The PCDF instrument

Based on the recommendations of a science team, the PCDF is a multi-user experiment facility capable of providing in-depth knowledge and understanding of the crystal growth process of biological macromolecules under microgravity. ESA has a study and development contract with a consortium of European industries led by Astrium (D), with subcontractors EADS-Launchers (F), Laben (I),



The European Drawer Rack with the PCDF electronic unit integrated as a drawer (top middle, right side) and the process unit integrated as a locker (bottom middle, right side). (ESA/D. Ducros)

Lambda-X (B), Verhaert D.D. (B), Imec (B) and Dierks & Partners (D). The first two phases of conceptual definition (Phase-A) and detailed definition and technical bread boarding (Phase-B) were conducted between 1996 and mid-1998. The last two phases of detailed design and development, manufacturing and testing (Phases-C/D) began in mid-1999 and will be completed by the end of this year.

The PCDF consists of two parts: the Process Unit and the Electronics Unit, respectively accommodated in an ISS locker (43x25x50 cm) and an ISIS drawer (43x35x60 cm).

The central part of the Process Unit is the process chamber, a sort of incubator, containing four experiment reactors. The Process Unit provides two independent temperature-control levels. The first is the sealed process chamber with its temperature controlled to 14-30°C; the second controls by individual Peltier elements each of the four crystallisation reactors within ±10°C of the process chamber temperature, i.e. 4-40°C. The experiment reactors carry drives to inject individual solutions into the reactor, and a stirrer. Three types of reactors will be available: batch, dialysis and extended length dialysis. The PCDF advanced diagnostics incorporate in the process chamber a monochrome digital video camera with a wide field of view and microscope optics, a dynamic light scattering system and a Mach-Zehnder interferometer. For future applications, the PCDF can be expanded to allow a second dynamic light-scattering channel and measurements in osmometry and pH-metry.

The Electronics Unit drawer houses all the controls for executing the experiments and for the PCDF diagnostics: the Power and Data Electronics, the main electronics unit, including a power unit, a central processor unit, a control electronics and an optical and video controller unit; and the Light Scattering Unit. Both units are cooled by a cold plate that uses the rack's moderate temperature water loop.

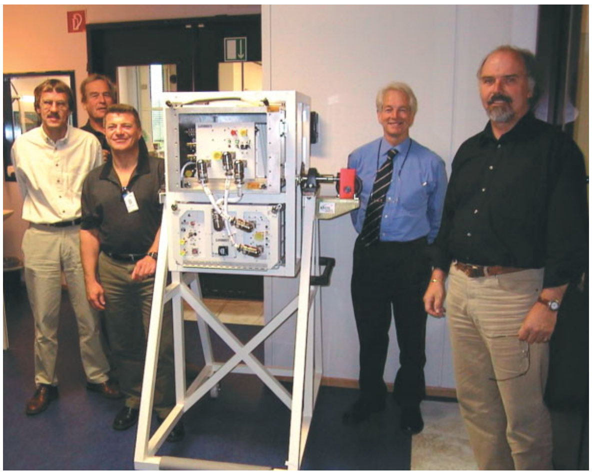
The diagnostics system allows scientists to control the experiment processing in a fully automatic mode (timeline-controlled) or in a semi-automatic mode (by uplink commands).

In order to provide experience, several ground units, including a Laboratory Model and a Science Reference Model, are being developed for the scientific community to conduct crystallisation experiments similar to those with PCDF in orbit.

PCDF will be accommodated in ESA's European Drawer Rack, relying on the EDR for video management, 28 Vdc power generation, telemetry and telecommand routing, and water cooling. For transport to and from orbit, the powered Process Unit will be accommodated in an active Shuttle middeck locker to provide a temperature-controlled environment for sensitive experiment solutions. When docked with the Station, the Process Unit will be transferred into its ISS Locker in the EDR. The Electronics Unit will be launched in the EDR with the Columbus module.

Conclusions

The PCDF will be a powerful new instrument for *in situ* studies of biological macromolecular crystallisation processes in microgravity aboard the Space Station from 2005. In addition, the post-flight analysis of crystals brought back to Earth will add structural information for correlation with these flight data.



The PCDF Engineering Model prior to testing with the ESA and Astrium projects team in May 2003. (R. Menzl)

Optimal scientific utilisation of this new facility will be achieved via collaborative projects involving scientists offering complementary expertise. PCDF heralds a new approach, proposed by an international core of scientists and supported by ESA, in understanding the mechanisms of crystallisation of biological macromolecules. ■

Matroshka

Measuring Radiation Hazards for Spacewalkers

Jan Dettmann
ISS External Payloads,
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Jan.Dettmann@esa.int

Guenther Reitz
Matroshka Principal Investigator & Industrial Project Manager
DLR, Linder Höhe, D-51147, Cologne, Germany
Guenther.Reitz@dlr.de

Introduction

Matroshka will measure the radiation doses that astronauts face during spacewalks. Surprisingly, these are still not well known. Knowing the doses suffered by sensitive body organs is crucial for assessing the hazards from cosmic radiation. Mounted outside Russia's Zvezda module on the ISS for a year, the multi-user Matroshka will record the radiation doses at different depths in a human mannequin on a simulated EVA. It provides:

Matroshka will help to make spacewalks safer for astronauts ...

- simulation of the human body and organs with respect to size, shape, position, mass density and nuclear interactions;
- chemical and physical stability of tissue substitutes in the vacuum of space;
- mounting of passive and active detectors in the body and spacesuit elements;
- temperature monitoring and control;
- atmospheric pressure monitoring;
- experiment and housekeeping data acquisition, temporary storage and transfer to the onboard data management system;
- delivery of telemetry data to the Payload Data Control Server for facility monitoring by Mission Control Center-Moscow;
- mechanical, electrical, thermal, pressure and data interfaces to Zvezda;
- disassembly/assembly to exchange the passive experiments inside Zvezda.

Simulated organs and real bone are seen in this tomographic image.

Components of Matroshka

Matroshka is housed in a container with a total height of 1100 mm; mass is 68 kg. The facility requires 40 W of power. The protective canister, of carbon fibre reinforced plastic with an atmosphere of oxygen, to some extent simulates a spacesuit.

The Phantom

The Phantom is designed of natural bone and material equivalent to human tissue. Lower-density material simulates the lungs. The Phantom is sliced into layers 25 mm thick and stacked around a mandrel for stability. The slices carry most of the sensors to measure the radiation doses at organ sites such as stomach, lungs, kidney, colon and eyes. In addition, the Phantom carries a coat of multi-layer insulation (MLI) equipped with Thermo-Luminescence Dosimeters (TLDs) to measure the skin dose. One Dosimetric Telescope (DOSTEL) is mounted on the head and the Tissue Equivalent Proportional Counter (TEPC) in front. The passive sensors must be returned to Earth for evaluation.

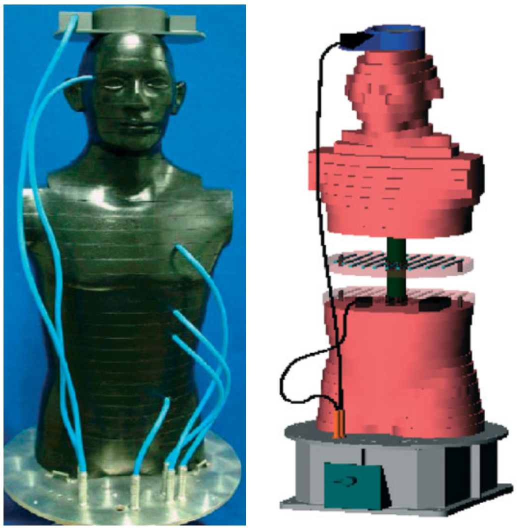
The base structure contains the electronics for the experiments and data-handling systems to communicate with Zvezda.

Dosimeters

Measuring the complex radiation field calls for a range of detectors. Active detectors will measure single particles and deliver their data to Zvezda, while the passive detectors will accumulate the particle data for evaluation on the ground after the year's exposure time.

DOSTEL (Dosimetric Telescope): a charged-particle telescope using three sandwiched silicon detectors to monitor the particle flux, dose-rate and linear energy transfer (LET) spectra of radiation from the Van Allen belts, deep space and the Sun.

TEPC (Tissue Equivalent Proportional Counter): a low-pressure ionisation chamber surrounded by 1.9 mm of tissue-equivalent material (A-100). All types of radiation will be measured. It is able to record a LET-spectrum every minute.



Matroshka consists of 25 mm-thick slices.

HiLRS (High-LET Radiation Spectrometer): solid-state microelectronics measuring the deposition of energy in p-n junctions with dimensions similar to a biological cell. The pulse height of the signal is proportional to the particle LET. It measures preferentially the high-LET particles.

SSD (Silicon Scintillator Device): a plastic scintillator cube covered by silicon detectors. The light output is proportional to the radiation dose. This dosimeter discriminates against charged particles and therefore measures the neutron dose.

TLD (Thermo-Luminescence Dosimeter): electrons are trapped in lattice imperfections in the TLD crystal under the impact of the radiation. When heated, the luminescence signal is proportional to the radiation dose. The dosimeters are distributed every 2.5 cm to give a depth-dose profile within the Phantom.

PNTD (Plastic Nuclear Track Detector): particle radiation produces latent tracks which can be made visible by an etching process. From these, we can generate LET spectra, and particle fluxes and spectra.

Operation and Status of Matroshka

Several Matroshka models will be delivered to RKK-Energia for cosmonaut training and tests:

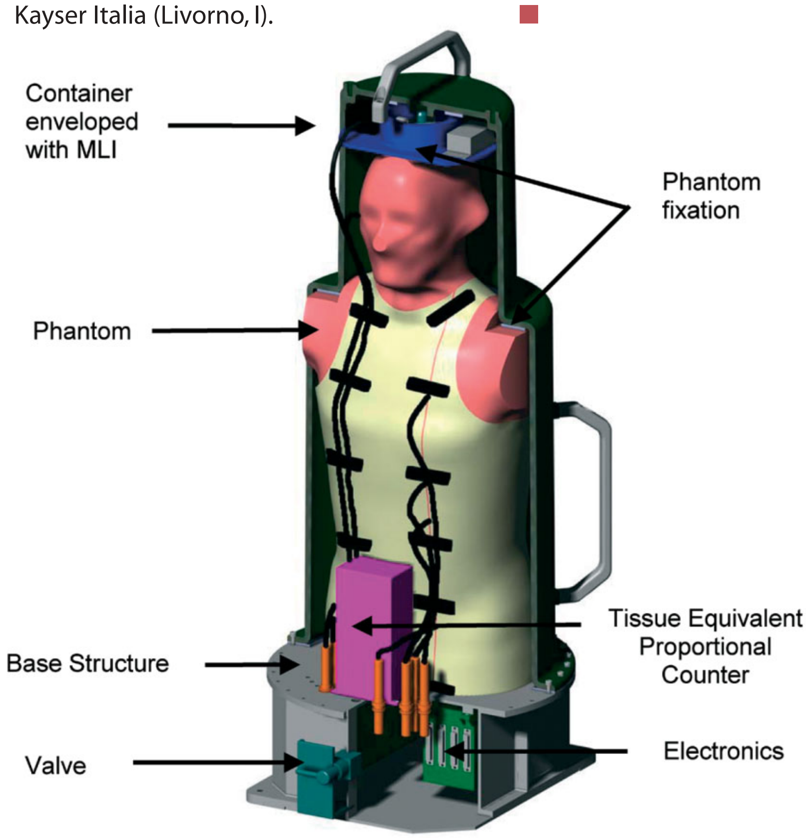
- Training Model 1 for EVA training (water tank);
- Training Model 2 for ISS internal training;
- Engineering Model for Complex Integration Tests;
- Flight Model.

Training Model 1 was successfully tested in the Neutral Buoyancy Laboratory of the European Astronaut Centre in Cologne in 2002. The EM will be delivered to RKK-Energia in June 2003. The FM is being built now; delivery and final acceptance are planned for November 2003.

Matroshka will be launched aboard a Progress unmanned ferry in January 2004 and transferred into the Russian Segment. The crew will perform an EVA to mount it outside Zvezda on a 'Universal Working Platform', produced by RKK-Energia. Matroshka will remain there for a year, until an EVA returns it inside. The MLI surrounding the canister and its embedded passive sensors will be removed during the EVA and packed into a special bag for return to Earth. Inside the Station, the container will be opened and the slices slid out one by one to remove the TLDs for bagging and delivery to ground. Accurate analysis requires no more than 2 months' total storage time in orbit.

Participating Industry

The ESA facility is under the project leadership of the German Aerospace Centre (DLR). Facility assembly, integration and test, Phantom preparation, experiment integration and processing are also the responsibility of DLR. The container and base structure are being built by DTM Technologies (Modena, I). Electronics and software development are by Kayser Italia (Livorno, I).



Pointing the Way

Hexapod Ready for Delivery

Marco Baccheti[1] & Aldo Petrivelli[2]
[1]Hexapod Payload Accommodation Engineer; [2]Hexapod Payload Integration and Operation Manager
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Marco.Bacchetti@esa.int; Aldo.Petrivelli@esa.int

Introduction

SAGE III, the Stratospheric Aerosol and Gas Experiment developed by NASA's Langley Research Center (LaRC), was one of the first scientific external payloads selected for the ISS. It was conceived for a spacecraft able to provide ±1° pointing accuracy. Since the Station's attitude can vary by several degrees over a long period, it was necessary to provide separate nadir pointing. For this task, NASA selected the hexapod-based pointing system proposed by ESA.

ESA's Hexapod pointing system is ready for delivery for its first mission on the ISS ...

Hexapod Mechanical Assembly without insulation blankets.

Hexapod development began in 1998, with Carlo Gavazzi Space (I) and Alenia Spazio (I) as prime contractor. The qualification campaign on the linear actuator, the system's most critical element, was completed in 2002. The flight unit is now completing testing and will be delivered to NASA/LaRC by July 2003.

The Hexapod System

Hexapod's key performance is its nadir pointing accuracy of ±90 arcsec, with a pointing stability of 0.0025°/s, in a pointing range equivalent to an 8° cone and with an angular rate of at least 1.2°/s. Hexapod determines attitude based on the ISS-provided attitude state vector and applies an attitude correction matrix to take into account the local deviations at the mounting location.

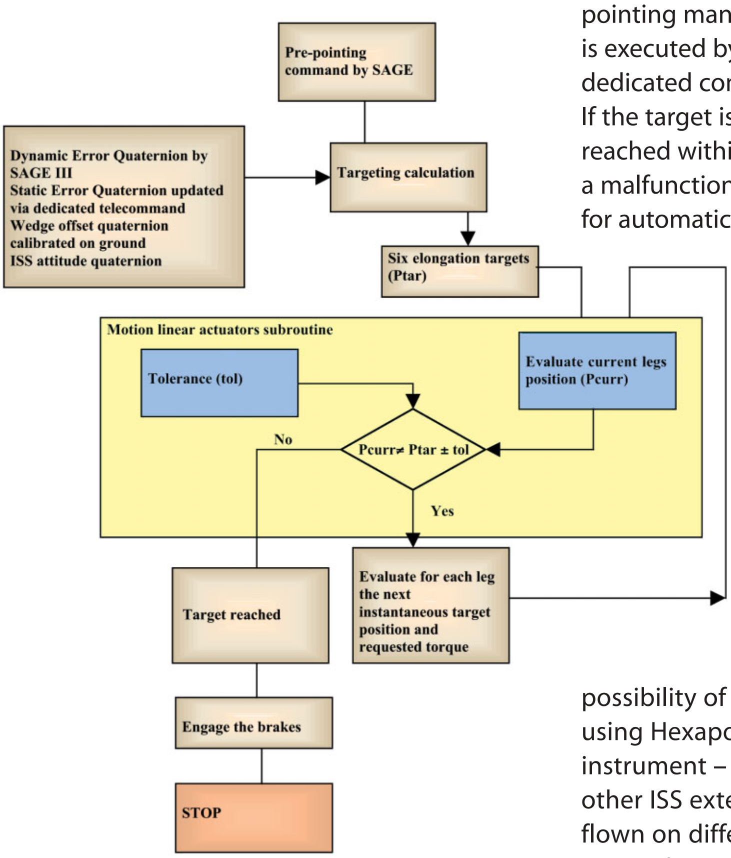
The Electronic Unit (HEU) and the Mechanical Assembly (HMA) are the two major constituents. The HEU is the integrated power and control unit that handles power distribution, telemetry and telecommand management, data processing, command and control. It provides the computer control for the coordinated movement of the six linear actuators. The flight software resides in the Standard Payload Computer (SPLC). The HMA includes six electromechanical linear actuators connected to a bottom flange and to an upper platform. The electromechanical linear actuator is a key element in the hexapod mechanisms. It has to guarantee a positioning accuracy as given in Table 1. A DC 3-phase brushless motor is installed in direct drive frameless configuration inside the linear actuator. The stator is installed inside the motor cage, and the rotor is installed on the satellite screw shaft. The motor can provide a continuous torque of 0.7 Nm up to 150 rpm, and a peak torque of 1.4 Nm. A brake locks the rotor when the final position of the upper platform is within the required accuracy, preventing the satellite roller screw back driving during the reentry phase. The brake system is designed to resist a torque of at least 6.3 Nm. The angular position of the linear actuator with respect to a fixed reference is measured through an encoder. HMA's other important element is the off-loading device around the hexapod mechanism to block the upper platform and protect the actuators during launch, thereby preserving their high accuracy for supporting the scientific mission.

Linear Actuator Qualification Test Campaign

A qualification model of the LA, fully representative of the flight unit, underwent qualification testing starting in December 2001. Reduced EMC and conducted emissions were well below the specified threshold. The dwell and random vibration qualification testing simulated the overall launch environment. Full and reduced functional tests were performed before and after thermal vacuum, life cycling, vibration according to: position accuracy; position repeatability; positioning resolution; actuator efficiency; linear velocity; brake release test; brake reduced torque test. Also important were the LA brake and friction tests. Table 1 shows the main results.

Finally, in June 2002, a static test concluded the qualification campaign: encoder rotation below a certain threshold recorded under ultimate load; no brake slipping or excessive actuator elongation detected; no actuator structural damage or loose parts detected; no braking device damage detected.

Hexapod Control Algorithm



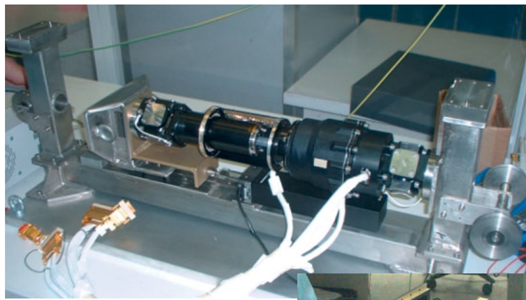
The control algorithm (see figure) provides the pointing corrections from orbit to orbit. The target is evaluated at the beginning of each manoeuvre from: dynamic error quaternion issued by SAGE III; static error quaternion, updated via dedicated telecommand; wedge offset quaternion, calibrated on ground; ISS attitude quaternion received every 1 s.

Table 1. Hexapod Full Functionional Tests.

	Required Value	*Measured Value*	*Remarks*
Position accuracy	< 25 mm	7 mm	as maximum
Position resolution	< 10 mm	OK	
Position repeatability	< 25 mm	9 mm	3σ value
Linear velocity	≥ 5 mm/s	OK	
LA friction test	< 0.5 Nm	0.23 Nm	
Brake reduced torque tests	< 35 counts	17 counts	applying 6.3 Nm torque

The target quaternion is transformed by the onboard software into six elongation targets to be reached by each of the six legs. The motion of the linear actuators is coordinated such that they all reach the target at the same time. Hexapod is declared 'on-target' when all six legs reach their target elongation and hold it for 1 s. This pre-pointing manoeuvre is executed by a dedicated command. If the target is not reached within 20 s or a malfunction is detected, an error is declared for automatic transition to stand-by mode.

Linear Actuator Qualification Model on the test bench.



Hexapod Electronic Unit during integration.

Conclusions

The Hexapod project is now completing the flight unit testing and approaching delivery to NASA for the final integration with SAGE III at LaRC this year. The availability of the Express Pallet and the flight to the Station remain unsolved. LaRC management is currently investigating the possibility of alternative options, including using Hexapod with a different scientific instrument – it is designed to be adaptable to other ISS external payloads and payloads flown on different carriers. Controlling payload attitude and position with six degrees of freedom makes Hexapod attractive for many space applications where the relative displacement of two systems has to be controlled to very high accuracy.

On Station
ISSN 1562-8019

The Newsletter of ESA's Directorate of Human Spaceflight

This newsletter is published by ESA Publications Division. It is free to all readers interested in ESA's manned spaceflight and microgravity activities. It can also be seen via the website at http://esapub.esrin.esa.it/

For a free subscription or change of address, please send an email to esapub@esa.int

ESA Publications Division/SER-CP
ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands
Fax: +31 71 565-5433

Editors: Andrew Wilson (Andrew.Wilson@esa.int) & Catriona Gouder
Contributing Writer: Graham T. Biddis
Design & Layout: Eva Ekstrand & Carel Haakman

Habla ISS

Spanish primary school children will talk with ESA Astronaut Pedro Duque when he is aboard the Space Station next October. ESA, in collaboration with the ARISS (Amateur Radio on the ISS) association is organising the 'Habla ISS' project. Children from Spain's 14 000 primary schools were invited by Pedro on 10 April to take part.

Educational material is provided on the project's website (in Spanish) at *www.esa.int/hablaiss*. The site is designed to be used directly by the pupils, with attractive colours and pictures guiding them to the lessons, activities and questionnaires. They can learn and play in the classroom to discover 'What is it like to be an astronaut?', 'What is weightlessness?' and 'What is the International Space Station?'

Pedro Duque, age 5.

All Spanish primary school classes are invited to participate in a national contest; the prize is the opportunity for four classes to talk live via radio contact with Pedro aboard the ISS. This event will be hosted at the 'Verbum Casa Das Palabras' museum in Vigo, Spain.

To enter the contest, each class has to submit the questions they want to ask Pedro and either a drawing or a story on the theme 'An astronaut and the ISS'. The winners will be selected on the basis of the drawings and stories. At ESTEC, Spanish-speaking staff and trainees will help in evaluating the contributions.

Main page of the Habla ISS site: www.esa.int/hablaiss

From the Juan Alonso Rivas primary school in Colomera, Spain

From the San Juan Bosco school in Madrid, Spain

Spain's ESA Delegation has kindly invited the children of Portugal to participate in this exciting project. One class from Portugal will be selected through this contest to join the event.

The Spanish Soyuz mission is scheduled for October 2003. Pedro Duque will lift off from the Baikonur Cosmodrome aboard a Russian Soyuz spacecraft. He will fly in space for 10 days, living and working in the ISS, 400 km above the Earth. During his stay, Pedro will take time out from his busy work schedule to talk to the competition winners live from space.

Building the 'Habla ISS' project was helped by the experience ESA has acquired in educational activities. The advice given by primary school teachers during the 'TeachSpace 2003' workshop at ESTEC in March 2003 was of great help:
– the importance of active participation by children;
– the importance of diversity;
– the importance of having an objective: talking with Pedro!

Further information?

If you want to know more about this educational project, you can look at the website at *www.esa.int/hablaiss* or contact us via email at *habla.iss@esa.int* or *Caroline.Pujol@esa.int*